Anomalous em signals and changes in resistivity at Parkfield: Collaborative research between the universities of California at Berkeley and Riverside and Oregon State University

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Investigations Undertaken

Fluctuations of resistivity are monitored with an array measuring natural electric currents (telluric currents) in Parkfield. Telluric coefficients x and y relate the electric field on dipoles to arbitrarily chosen reference dipoles 7 and 8 (Figure 1):

$$D_i = x\,D_7 + y\,D_8\,. \tag{1}$$

Fractional daily variations of the telluric coefficients are computed and then compared to the earthquake record from Parkfield in order to determine if significant changes occurred prior to or at the time of local earthquakes. Changes in the telluric coefficients are related to changes in resistivity, albeit in a complicated manner because the earth is heterogeneous.

In late 2004, the M6.0 Parkfield earthquake finally occurred. While no fluctuations in telluric coefficients were observed, a transient coseismic signal was recorded with both the main shock and the two M5 aftershocks. No transients accompanied any smaller aftershock. The transient signals are identified by subtracting the signal predicted using (1) with the best fit telluric coefficients from the observed signal:

$$R_i = D_{i,obsv} - D_{i,pred}\,. \tag{2}$$

The residual signal is approximately 100 times smaller than the observed signal and contains noise as well as any tectonic signals, making the process of identifying the latter difficult.

Because the next Parkfield earthquake occurred in 2004 and the goal of this experiment was to record signals through the earthquake, this experiment is concluded. No funding was requested to continue the array past January, 2006. Some components of the array may continue as an Earthscope site, however.

Results

Most of the effort this year has been spent attempting to understand what caused the coseismic signals from 2004. The signals shown in last year's report were the result of transient changes in electric potential at electrodes, primarily Hr and Ff (Figure 1). The transient changes are puzzling because their magnitudes do not vary with distance from the fault or hypocenter, and persist for several hours. The signs of these changes for the aftershock are opposite to those of the main shock, leading to the question of what is different between these two earthquakes (other than magnitude). At this time, we are examining the spatial relationships between the electrodes with largest signals and the earthquakes.

No significant fluctuations in the telluric coefficients were observed in 2005 during the post-seismic period (Figures 2-6). After Day 223, problems with the telephone line cable to Hr degraded the array performance because Hr is a common electrode for both reference dipoles (7 and 8). Verizon is attempting to fix this problem.

Because I have elected to turn off the array now that the experiment has concluded, 2005 will be the last full year for which telluric data are available from the Northern California Earthquake Data Center.

Non-technical Summary

Prediction experiments worldwide fall into two types: widely distributed instruments monitoring signals from both local and distant earthquakes; and dense clusters of instruments focused on a specific earthquake zones. The Parkfield experiment is unique because it focuses a broad range of geophysical instruments on a specific earthquake source. The distribution and movement of fluid likely affects the generation of earthquakes, and electrical properties of rocks can detect this fluid. Monitoring of the electrical resistivity may detect a change before the earthquake but more importantly, will show how fluid affects the fault zone prior to its failure. The M6.0 characteristic earthquake occurred in September, 2004 with no accompanying resistivity changes larger than 0.2% before, during, or after the earthquake. However, a transient electrical voltage was triggered by the earthquake and may be related to fluid flow.

Reports published

None.

Data availability

Processed results and original time series data from 1988-2003 are available via anonymous ftp at vortex.ucr.edu in the directory pub/emsoc/1/pkfld. Time series for 1988-1997 are also available at the site.

References

Larsen, J.C., Mackie, R.L., Manzella, A., Fiordelisi, A., and Rieven, S., Robust smooth magnetotelluric transfer functions. *Geophys. J. Intl., 124*, 801-819, 1996.

Park, S. K., Monitoring resistivity changes prior to earthquakes in Parkfield, California with telluric arrays: *Journal of Geophysical Research*, 96, 14211-14237, 1991..

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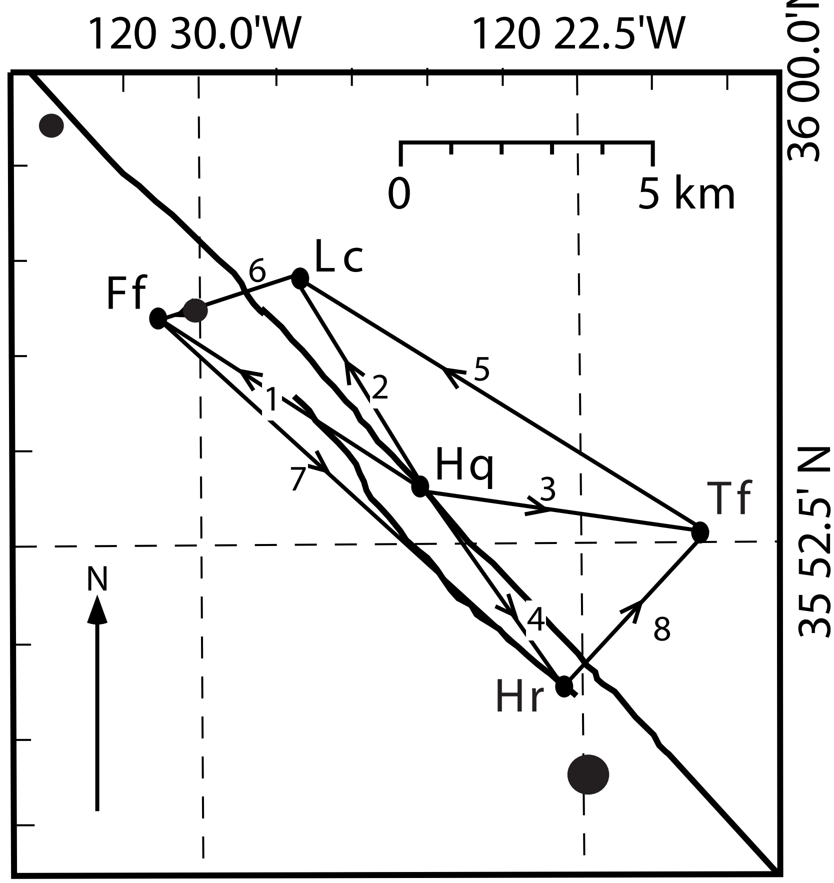
Figure 1 - Location map showing array in Parkfield. Dipoles 1-8 are labeled and polarities are shown with arrows. Heavy Black lines are strands of the San Andreas fault. Dipoles 7 and 8 are used as references for dipoles 1-6. The 2004 M6.0 earthquake is shown with single large dot to south of Hr, and the two M5.0 aftershocks in 2004 are shown with smaller dots northwest of the array.



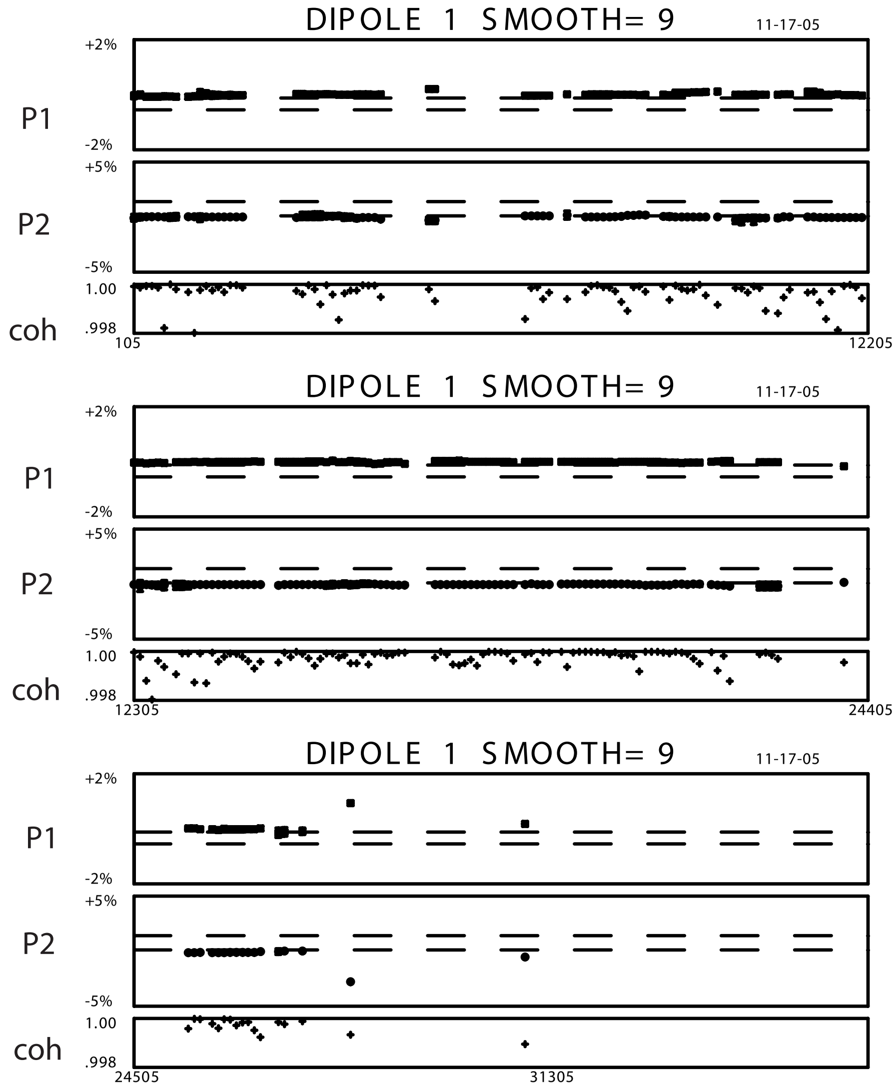


Figure 2- Projections of daily fluctuations of telluric coefficients for dipole 1 in directions perpendicular (P1) and parallel (P2) to the San Andreas fault. Coherency for the signals is shown as a measure of data quality. Nine day running average is used to smooth out the daily fluctuations and achieve stabilities of < 1%.

Data are plotted through Julian day (33004 day 313 in 2005). Sparse points after Day 223 are due to telephone line problems.

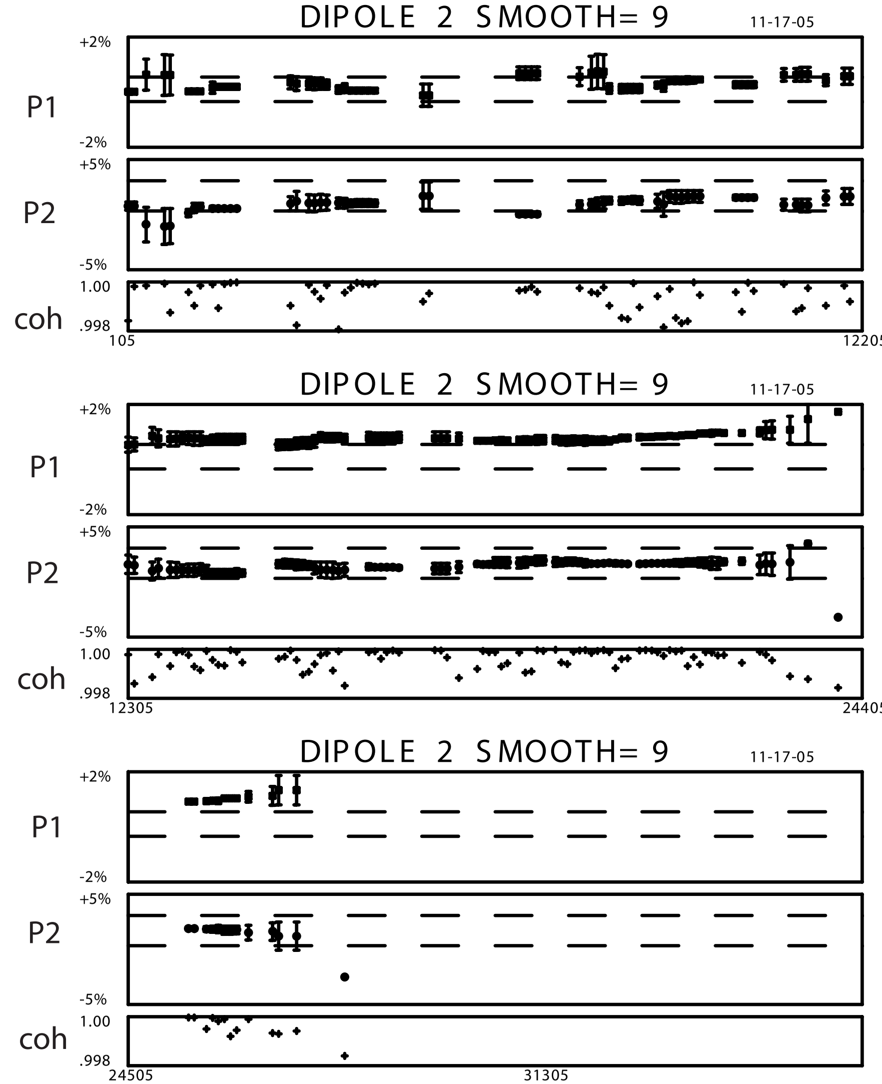


Figure 3- Projections for dipole 2 for 2005. See Figure 2 caption for explanation. Note that this dipole is much noisier than dipole 1, as indicated by the larger error bars. Gaps in data are due to noisy telephone line to electrode at Hr (Figure 1).

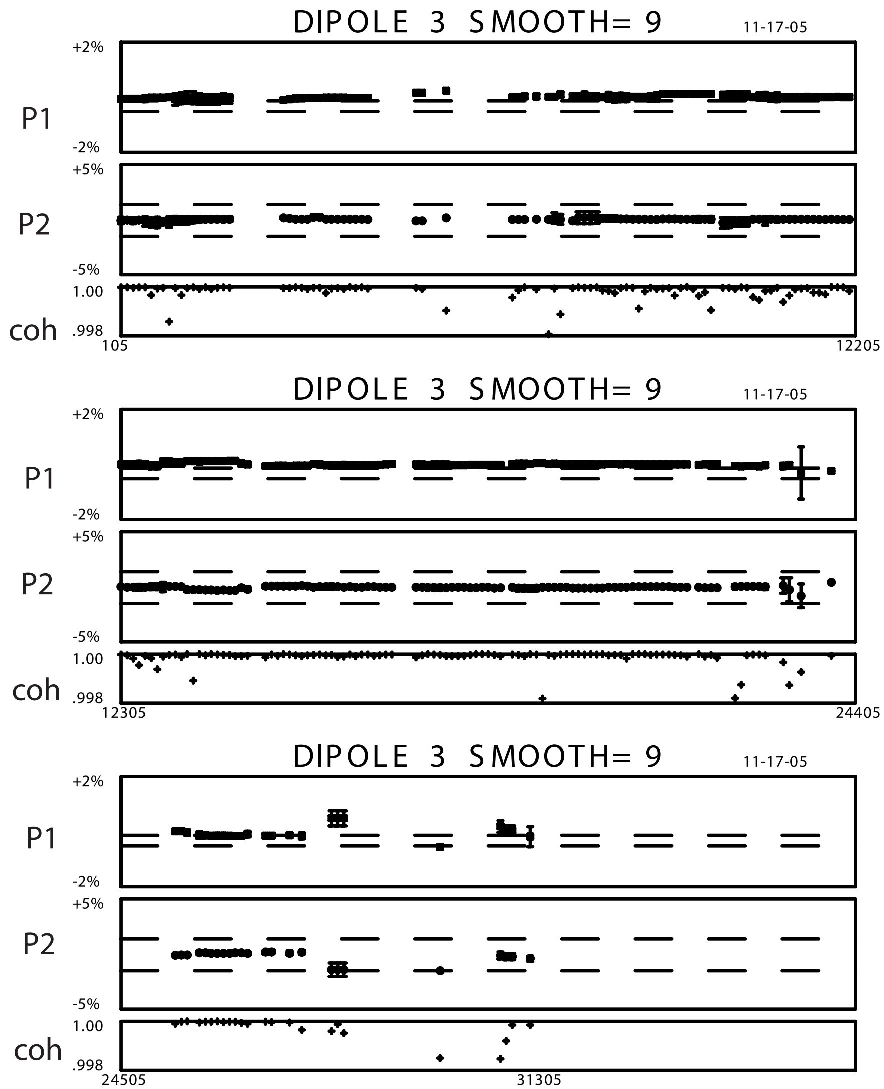


Figure 4- Projections for dipole 3 for 2005. See Figure 2 caption for explanation.

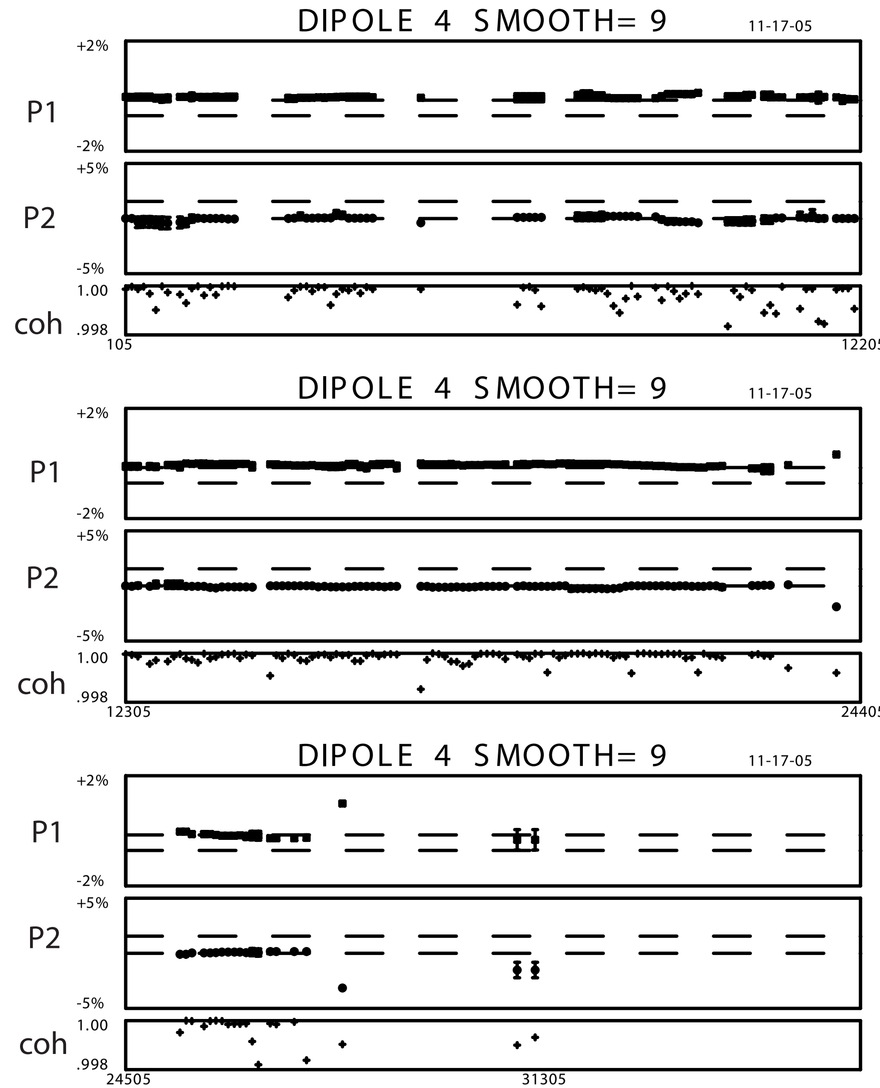


Figure 5- Projections for dipole 4 for 2005. See Figure 2 caption for explanation.

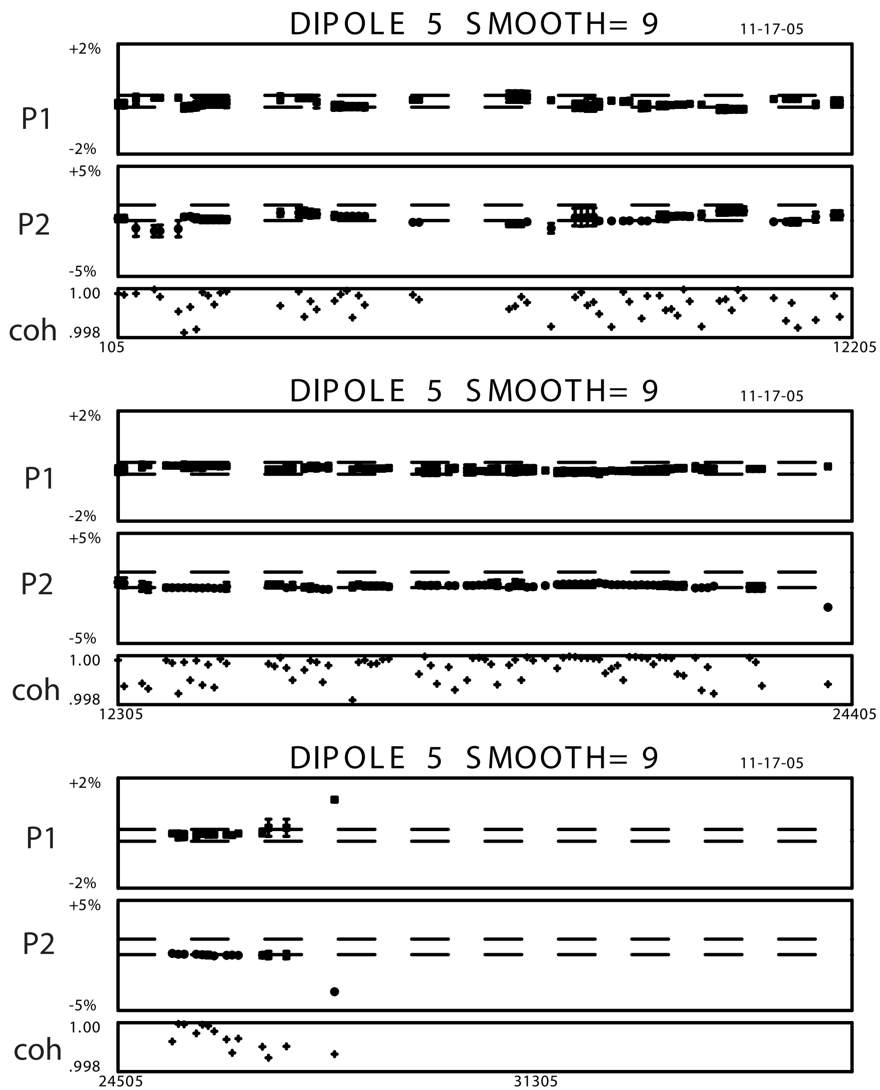


Figure 6- Projections for dipole 5 for 2005. See Figure 2 caption for explanation.

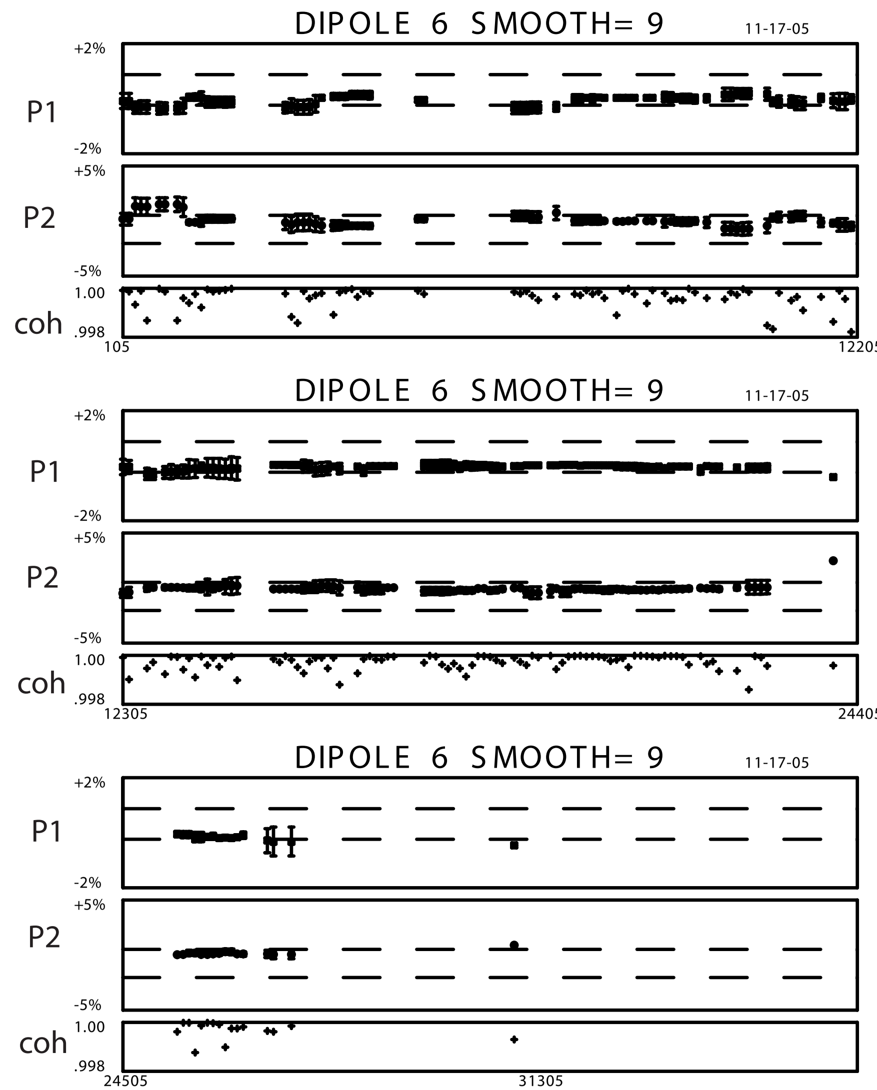


Figure 7-Projections for dipole 6 for 2005. See Figure 2 caption for explanation.